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SPECIFICATION NO. 865,765

By a direction given under Section 17 (1) of the Patents Act 1949 this application proceeded in the name of RANSBURG ELECTRO-COATING CORP., a Corporation organised and existing under the laws of the State of Indiana, United States of America, of 3939 West Fifty-sixth Street, Indianapolis, State of Indiana, United States of America.

THE PATENT OFFICE

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**ERRATA**

SPECIFICATION No. 865,765

Page 7, line 16, *for* "comprlser" *read* "com-  
prises"

Page 14, line 105, *for* "aeosition" *read*  
"deposition"

THE PATENT OFFICE  
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reduction of paint losses and the reduction in other costs, including the cost of labour of coating, but at the same time electrostatic spray coating systems have certain limitations in usage which have restricted their wider adoption. One such limitation is due to the fact that proper electrostatic atomization and efficient deposition of spray coatings requires the employment of an electrostatic field established by relatively high effective voltages, for example of the order of one hundred thousand volts. Voltages of this order have many unexpected characteristics, and present especial difficulties relative to safety both as to fire and as to shock hazard to personnel.

As many of the spray coating materials employed are inflammable, and in some cases highly so, it has at all times been necessary to provide a minimum spacing between the electrodes and the articles in order to avoid the risk of sparks or arcs of sufficient intensity to initiate a fire or explosion. These considerations have dictated the necessity of confining the use of the various systems now employed in commercial practice to installations wherein the distance between the charging electrode and the articles to be coated is maintained within predictable limits. For example, it is very convenient in a commercial installation to have the articles suitably mounted on a travelling conveyor so that they are successively moved to pass the location where one or more atomizers are provided, and in such a case the charging electrode is stationed in fixed relation to the path of movement of the articles. In this way the necessary distance, and in particular the minimum spacing between the electrodes and the articles, can be controlled with sufficient accuracy to ensure the avoidance of disruptive discharges, such as might cause a fire or explosion. Sufficiently more than the minimum sparking distance must be allowed to provide for possible but fortuitous variations in the spacing; for example in installations where mechanical atomization is employed and a separate charging electrode is provided, it has been the practice to space the charging electrode from the article a distance which is twice the sparking distance. Maintaining this distance results, of course, in a decrease in efficiency of the operation, as the average potential gradient is necessarily equally reduced. This allowance of additional spacing for safety purposes, however, has been dictated by the practical necessities which result in variations in

electrode-article spacing during normal operation of a system of this nature. For instance, many objects carried on conveyors of the type referred to are subject to some movement due to swaying, or may lie in a different plane due to a bent hanger, which causes the articles to move to and from the charging electrodes. In other instances, articles of irregular shape may be rotated while being sprayed, and due to their irregular shape and the rotation, the effective electrode-article spacing will change during the spray coating operation.

The need to provide a system which is free from danger of discharge sufficient to cause ignition of the paint solvent is not the only requirement ensuing from the use of high voltage, and it is very desirable to arrange that shock to personnel should be avoided. For example, the paint solvent may be non-inflammable, but in such a case it would still be highly desirable to provide means to ensure that the human operator could not approach the charging electrode sufficiently closely to receive a shock from the points at high voltage; thus, even in an installation in which the fire or explosion risk is low it is still necessary to make use of a high degree of mechanisation.

In general, therefore, in an electrostatic spray painting equipment for commercial use it has always been the practice to make use of apparatus, such as conveyors to ensure minimum electrode to article spacing and to prevent or obviate the need for an operator to approach closely to the high voltage parts. In turn, this has meant that electrostatic spray painting has found its widest application in the finishes of comparatively large numbers of similar articles.

This consideration is in some contrast with the conventional air operated hand held spray gun. The air gun is inefficient in terms of paint utilisation as much of the paint consumed by the gun fails to reach the article to be painted, but it has the advantage that the operator has almost complete freedom of movement in directing the paint spray onto the article. So far as we are aware, however, it has never been possible to realise in a commercial installation the advantages of electrostatic spray painting in an equipment in which the operator had the facility of movement afforded by the air gun. The reasons will be apparent from the foregoing: firstly, with a hand

held electrostatic gun there would be no limitations on the minimum distance that might exist between the charged or high potential parts of the gun and the article, and this spacing would be liable to fortuitous variation into that range of separation which might result in undesired discharge and secondly, with the hand held gun in which parts of the gun would be at dangerously high voltage in use, the risk of shock to the operator would be very great. The term "gun" is used somewhat loosely in the electrostatic painting art; for the purpose of the present invention it can be taken, in its broadest sense, as comprising that part of the apparatus to which the paint is fed and from which it emerges in atomised form; the atomised paint may or may not be projected from the gun, and the gun may or may not be suitable or primarily intended for use in the hand.

The present invention is concerned with the provision of means, in an electrostatic spray painting apparatus, whereby any tendency of the system to cause a discharge can be controlled. The invention can be used with advantage in any system in which the electrode-article spacing is liable to fortuitous variation, as described above, with the object of reducing the danger of ignition of the solvent; the invention can also be applied to a system where the avoidance of human shock is of prime importance, and it can be used in applications where both advantages are desired. The invention thus makes possible a system which permits the use of a fully safe, hand-operated electrostatic spray gun.

The invention is based upon two facts that we have ascertained and verified that the propensity of any electrostatic spray painting apparatus to give rise to a discharge that is objectionable in either of the respects mentioned above can be controlled by adoption of two features in the system.

The first feature concerns the electrical circuit which extends from the charging electrode to the article, including the source of high voltage, and consists in so arranging this circuit that it is responsive to changes in the length of the air gap, whereby the voltage of the charging electrode is substantially reduced as the air gap between the electrode and the article decreases. This result can be secured by giving the circuit an appropriately high effective impedance.

The provision of a suitable circuit

impedance in this manner assists in different ways in reducing the tendency to or effects of discharge in the system. For example, if the value of the impedance is sufficiently high in relation to the potential employed and the air gap commonly present, the effect of variations in the air gap, which would normally have a direct and major influence on the potential gradient, will be substantially reduced, that is changes in potential gradient resulting from changes in spacing are reduced. Again, the impedance has an effect on capacity as will be apparent hereinafter. In embodiments of the invention described hereinafter the impedance takes the form of a resistance.

The second feature with which the invention is concerned relates to the effective capacity presented at the air gap of a charging electrode or electrode system. As used in the present specification including the claims, the "effective capacity" of an electrode system is not the same as the conventional electrical capacitance of the system, that is, it is not a measure of the ability of the system to store electrical energy, but rather it is a measure of the propensity or ability of a discharge from the system to shock personnel or ignite inflammable vapours. For the purpose of the present invention it is arranged that the charging electrode or electrode system has a low effective capacity; when we state herein that an electrode system has a low "effective capacity" we mean that the electrode system has such low true capacitance, or such combination of true capacitance and poor conductivity of the material of which it is formed, and shape (particularly as to "sharpness" or "bluntness" of its configuration), that, in an electrostatic coating system of the character with which we are here concerned, the energy contributed to a disruptive discharge between such electrode system and an opposed "blunt" electrode by the electricity stored in the electrode system is insufficient to render such discharge objectionable. We have found that if some portion of the charging electrode or of the system between the charging electrode and the impedance or resistance previously referred to is of highly conductive material, such as metallic wire or the like, such can be tolerated, provided that it is of such limited area that it has no substantial capacitance. In other words,

if highly conductive materials are to be used adjacent the air gap, their actual capacitance must be so low as to be within tolerable limits. If, on the other hand, their capacitance is greater than the tolerable amount, they must be of such low conductivity that the energy thereof cannot be discharged in such a manner as to produce an objectionable disruptive discharge.

It will be appreciated from the foregoing that a discharge can be objectionable in that it is liable to ignite an inflammable paint solvent, or alternatively to give a human being a shock which is painful or worse, depending upon circumstances it may be required that an electrostatic spray painting apparatus should be unobjectionable in either or both of these respects. Also depending upon circumstances a discharge can be objectionable in either one of these respects and not the other.

Broadly, therefore, the present invention consists of an apparatus for electrostatically spray painting an article, said article being substantially at earth potential, comprising a gun, capable of use in circumstances where the air gap between the gun and the article or earth is liable to fortuitous variation, said gun including a charging electrode, and means for establishing an electrical circuit including the earthed article, a unidirectional high potential source and said charging electrode, said gun being adapted in use to atomise paint and introduce said atomised paint into the field between the charging electrode and the article, wherein (a) the electrical circuit including said source is so responsive to changes in the length of said air gap as to reduce the voltage of said charging electrode sufficiently as the air gap between the gun and the article or other earthed object decreases, and (b) the charging electrode and any other parts of the gun which are at high potential in use and are manually or otherwise externally accessible have an effective capacity that is sufficiently low, to ensure that any discharge of electricity therefrom which will create fire hazard is avoided.

The invention also includes apparatus for electrostatically spray painting an earthed article, said article being substantially at earth potential, comprising a gun capable of use in the hand or in circumstances where a human operator has access to the gun, said gun including a charging electrode, and means for establishing an electrical circuit including the earthed article, a unidirectional high potential source and

said charging electrode, said gun being adapted to atomise paint and introduce said atomised paint into the field between the charging electrode and the article, the charging electrode and any other parts of the gun that are at high potential and are manually accessible in use having an effective capacity that is low and the electrical circuit including said source being so responsive to changes in the length of the air gap between the charging electrode and the article or operator as to reduce the potential of such part or parts sufficiently in relation to their effective capacity as the air gap decreases, to ensure that objectionable shock is substantially eliminated.

The invention also includes a method for electrostatically spray painting an earthed article, which comprises establishing an electrostatic field between a charging electrode and the article by means of a voltage source, the air gap between the charging electrode and the article or earth being susceptible to fortuitous variation into a range where objectionable discharge is liable to occur, which comprises supplying paint to an atomizer and introducing atomized paint into the field and including controlling automatically the potential across said air gap in accordance with variations of the length of the air gap, in such a manner that with a decreasing length of air gap the potential falls at a rate not less rapidly than that due to the inclusion in the circuit to said charging electrode of a resistance of two or more megohms per kilovolt of the source, whilst maintaining the effective capacity of the charging electrode not greater than that which would be provided by a metal sphere of a radius of 3 cms.

The invention further includes an apparatus for electrostatically painting an earthed article, comprising a charging electrode and capable of use in circumstances where the air gap between the charging electrode and the article or earth is liable to fortuitous variation, means connecting the article in an electrical circuit extending from a unidirectional high potential source to said charging electrode, means for atomising paint and introducing said atomised paint into said field, wherein said electrical circuit is so responsive to changes in the length of said air gap as to reduce the voltage of said

charging electrode sufficiently as the air gap between the charging electrode and the article or other earthed object decreases and the charging electrode and any other parts which are at high potential in use and are manually or otherwise externally accessible have an effective capacity that is sufficiently low to ensure that any discharge of electricity therefrom is unobjectionable, either as to shock or fire hazard or both.

The invention also comprises other features which will become apparent hereinafter.

As previously mentioned, atomizing devices embodying features of the present invention can be constructed in a manner which will maintain within a predetermined range the potential gradient between an electrostatic atomizing head and an article, regardless of changes in the space therebetween, and wherein dangerous and objectionable discharges may be prevented, even where the high potential electrode is accidentally brought into contact with the operator or with the article being coated. By reason of the foregoing, it is possible to produce a hand-held or manually manipulatable electrostatic atomizing device which is capable of the high efficiency performance of the electrostatic atomizing devices previously mentioned, yet may be used with perfect safety as a hand-held atomizer, and to improve materially systems utilizing a fixedly mounted atomizer.

Other features and advantages of this invention will be apparent from the following description and the accompanying drawings, in which:

Figure 1 is a perspective view of a system in accordance with the invention for electrostatically atomizing and depositing paint on the articles to be coated;

Figure 2 is a longitudinal view of the atomizing device shown in Figure 1;

Figure 3 is a fragmentary view, partly in section, showing in more detail the means for rotating the head of the atomizing device and for supplying liquid coating material thereto for atomization;

Figure 4 is a chart graphically illustrating, by appropriate curves, certain voltage and distance relationships;

Figure 5 is a longitudinal sectional view of another form of atomizing device adapted to be held in the hand and used in a system of the general character shown in Figure 1, and also having a rotating atomizing member.

Figure 6 is an elevational view of another system embodying our invention, atomization in this case being by a conventional air gun; and

Figure 7 is a partial elevational view at right angles to that of Figure 6 and along the line 7-7 thereof.

Referring now to the particular embodiment of the invention illustrated in Figures 1 to 3, it will be seen that articles 10 are moved in succession through a coating zone, the articles being here illustrated as garnish mouldings for the window openings of motor car bodies, an article difficult to paint effectively with conventional systems utilizing hand-held air spray guns. The articles are here shown as being moved along to the right of the drawing as illustrated, by hangers 11 in turn connected to a chain (not shown) on a conveyor track 12 of conventional overhead conveyor means, as illustrated. This movement is without rotation and the articles are shown as being painted on one side only (except for such "wrap-around" as may occur due to the electrostatic action), and it will be understood that in practice another man would normally be stationed on the other side of the line at a second coating station to provide a coating of the desired film thickness on the other side of the articles.

The atomizing device identified in general as 14 and to be more fully described in detail hereafter, includes a long body portion 15 with an outer housing of polyethylene or other non-conducting material with good high voltage insulating characteristics, and a rotating bell-like head 16 from the edge of which the liquid coating material is electrostatically atomized. The charged spray particles of paint or the like are then attracted to and deposited upon the articles under the influence of electrostatic forces, the articles being earthed and the high potential high voltage terminal of the power supply unit 17 being connected to the atomizing edge in a manner hereinafter more fully described and including a high resistance in the connection and close to the atomizing head 16.

In the system illustrated (and as may be best seen by also referring to Figure 3) a supply tank 18 supplies paint through a tube 19 to a pump 20, preferably of a positive displacement variable speed type driven by its own

motor. The output of the pump is delivered through a paint supply conduit 20a to the opening in a hollow shaft of an electric motor 22, this paint supply conduit continuing on up through a flexible conduit arrangement indicated in general as 23 leading to the hand-held atomizing device, the paint eventually issuing through a central opening in the bell-like rotating atomizer member 16 to be formed in a thin film on the inner surface of this member and to have the spray particles atomized from such thin film at the edge of the rotating member, as more fully described in specification 710920. As is more fully described in that specification the high potential electrostatic field existing between the atomizing edge and the articles draws the film edge into closely adjacent cusps with the spray particles or droplets issuing from the ends of these cusps during atomization.

Rotation of the atomizing head 16 is effected during operation by having the hollow shaft rotator motor 22 drive a hollow flexible metallic shaft 24 surrounding a paint tube 21, the outer sheath of the conduit assembly being a conduit 25 of polyethylene or other material having a good high voltage insulating property. High voltage, of at least 40,000 volts and preferably 70,000 volts or more, is supplied from the high voltage pack 17 (generally from the negative terminal thereof) through the lead 26 to the motor 22, the flexible metallic drive tube 24 conducting the high voltage to the atomizing device. The paint supply tank 18, the pump unit 20 comprising the pump and its motor, and the rotator motor 22, are all mounted on a support member 27 carried on legs 28 of ceramic or other rigid material of good high voltage insulating characteristics; and the pump motor and rotator motor are supplied with drive current (as conventional 50 cycle 230 volts AC) through isolating transformers with proper high voltage insulation so that the whole arrangement is maintained at high voltage with respect to earth. While not illustrated, these parts would normally all be enclosed in an insulating housing to protect against accidental contact of a person with any part at high voltage; and not only the input of the high voltage supply unit but also the isolating transformer inputs would have conventional on-off switches therein, so that the operator can terminate coating operation at any time merely by moving to the "off" position a master switch, or individual

switches provided in each input.

Referring now more particularly to Figure 2, the atomizing device is shown in more detail. The rotating bell-like atomizing member 16 is of nylon, polyethylene or similar material of good high voltage insulating characteristics. It has an axial opening 16a, an adjacent portion 16b which flares sharply outwardly from the axial opening, and a rim portion 16c extending forwardly more nearly axially with an inner surface about 15° off the axis, this portion being tapered to a relatively sharp forward atomizing edge 16d. The inner surface of the rotating member, from the axial opening clear to the atomizing edge, is covered with a coating 16e of a material which has high chemical resistance to the constituents of the paint or other liquid coating material being used, high mechanical resistance to abrasion by the material flowing thereover, and predetermined high electrical resistance characteristics. An alkyd resin enamel-like coating material with finely divided carbon particles therein has proved very satisfactory for this resistive layer.

For purposes of this invention it is sufficient that the material should have suitable chemical and mechanical resistance, and be of high electrical resistance while still permitting a flow of very small currents there-through. The resistance with which we are here concerned is what may be termed a point-to-point resistance, in that the factor of importance is the resistance to current flow from a given point on the surface to another surface point, as at the atomizing edge. While the device illustrated achieves its desired resistance characteristics by using a body material for the bell which is substantially completely non-conducting (as nylon) and a surface coating which has some slight conductivity, it will be understood that the rotating member could be formed of a single homogeneous material provided it had the desired point-to-point resistance characteristics and suitable mechanical strength. With a rotating bell member about 4 inches in diameter, a suitable size for a hand atomizing device, it has been found that the resistance from the apex (at the axial opening) to the rim or atomizing edge (when the same is placed in contact with a metal plate entirely around the extent of the rim edge) should be at least of the order of 10 megohms, and



preferably of the order of 100 megohms. In these circumstances the resistance per square (as for example a one centimetre square) would be of the same order of magnitude as the above-mentioned apex-to-edge resistance, but it is more convenient commercially to determine the resistance from the apex to the edge. It will also be understood that if rotating atomizing devices of larger diameter are used, it may be desirable materially to raise the resistance.

The bell member 16 is mounted on a rotating shaft assembly 29, as by rubber O-rings. This shaft assembly comprises a commercially available high value resistor consisting of a hollow ceramic tube 29a of about 12 inches in length, with an outer coating 29b of suitable high resistance material. A coating on the right-hand tip of the ceramic tube provides an electrical connection between the end of the resistance material 29b and the inner or apex portion of the high resistance coating 16e on the inner surface of the bell member. The entire resistor is held within a rigid carrier member 29c of synthetic resin or like material which rotates on bearing surfaces provided by an outer insulating sheath 30, which in turn lies within outer housing member 31 of polyethylene.

The outer sheath member 25 of the flexible conduit assembly 23 extends into the outer housing member 31, as may be seen at the left of the drawing, the whole assembly being held in the hand atomizing device by the co-operation of the cap 32 with an enlarged portion 33 moulded in the sheath tube 25. The hollow flexible metallic shaft 24 within the tube 25 is mechanically coupled, through a splined assembly 34, to the rotating shaft assembly 29 carrying the bell member 16. Appropriate liquid seals in assembly 34 ensure that all of the coating material flowing from the end of paint tube 21 is transferred into hollow shaft assembly 29. Paint supplied through the tube 21 passes through the hollow shaft and spreads out on the inside of the bell during rotation thereof to supply the atomizing edge with paint continuously at a rate determined by the operation of the positive displacement pump, a representative rate of supply being 100 ccs. per minute.

The circuit connection from the high potential terminal of the power supply is completed through the hollow flexible metal shaft (which is, however, sheathed from accidental contact by the

outer polyethylene tube), and any current reaching the atomizing edge must pass through the resistance not only of the high resistance inner coating 16e on the bell, but also through the extended resistance layer 29b, this being here shown as of sufficient extent to prevent any possibility of arcing around the outside thereof. It will be understood that suitable insulation can prevent the arcing regardless of the actual extent of the resistor. In parallel with these fixed high resistance values is a current path through the paint, from the point where it leaves the flexible metallic shaft end to the atomizing edge. While a highly conductive paint in the embodiment here being described would thus tend to nullify the value of the high resistance means just described, the resistance of the paint column in a passageway of the size illustrated (which would normally be only  $\frac{1}{8}$  or  $\frac{3}{16}$  of an inch in diameter) is such that the resistance through the paint is at least several hundred megohms and may be many thousands of megohms with the lacquers and synthetic enamels normally used in commercial spray painting. The total effective resistance to the atomizing edge must be at least two megohms per kilovolt applied by the high voltage source; with normal commercial operations it is preferable to have at least 300 megohms and normally 1000 megohms resistance or more. Most commercially used coating materials provide a shunt resistance considerably higher than this, so that if the fixed resistances are arranged to provide a resistance at or about this value, the total "working" or effective resistance will normally be approximately the same value. Even if paint is completely non-conducting for all practical purposes, as is frequently the case, the fixed resistances will provide the necessary voltage at the edge of the bell for atomizing and charging the spray particles.

Again referring particularly to Figure 1, the operator carrying out the spraying with the hand atomizing device would normally follow roughly around the metal framework comprising the garnish moulding, and should normally try to keep the atomizing edge of the bell member 6 or 8 inches away from the metal of the object, for example, if a 100,000 volt pack is being used. However, hand operation or any operation wherein there



are appreciable changes in air gap distances between the charging electrode and an article, introduces difficulty in an electrostatic coating system.

5 Variation in gap distance, if the voltage between the electrode and the article remains the same, obviously results in very considerable variation in the average potential gradient. Thus, if the  
10 bell and shaft were both of metal and connected to the 100,000 volt power pack, the average potential gradient at a 12 inch spacing would be only about 8000 volts per inch, whereas the average  
15 potential gradient at a 5 inch gap spacing would be 20,000 volts per inch. An electrostatic coating system of the kind just described, with atomization being effected electrostatically,  
20 achieves very high paint deposition efficiencies and is highly desirable commercially.

It will be seen that if there is included in the circuit resistance of the  
25 value mentioned above, such wide variations potential gradient will be reduced, and the resulting potential gradient will be within a satisfactory range, and very high potential gradients conducive to  
30 sparking are reduced.

However, it has now been found that there are optimum values of the average potential gradient, and that these do not remain the same regardless of spacing but  
35 vary in accordance with the gap distance. A gradient at the film edge which is too low does not atomize particles of the desired fineness for a quality coating; but improvement in atomization increases  
40 with the gradient only up to a certain point, and thereafter deteriorates rather than further improving.

We believe too high a voltage has certain field effects on the cusps causing at least some of them to merge  
45 and give undesirably large particles, and in any event to flail or whip around in a manner which also results in much poorer uniformity in the size of the spray particles. Whatever the full  
50 explanations may be, however, we have found that there is an optimum average potential gradient for electrostatic atomization, and that this does not remain constant with changes in gap  
55 spacing. For example, with a 4 inch metal bell rotating at about 1000 rpm and supplied with 100 cc per minute of a synthetic enamel, the optimum average  
60 potential gradient for electrostatic atomization at 12 inches is about 7,500 volts per inch; at 9 inches is about 9,000 volts per inch; at 6 inches is about 11,700 volts per inch; and at  
65 3 inches is about 17,000 volts per inch.

We have found, as may be best seen from reference to Figure 4, suitable selection of the control resistance keeps the voltage at the atomizing edge of the bell in close conformity with the optimum  
70 atomizing voltage throughout wide variations in gap distance, as from 3 inches to 12 inches. This results in maintaining the quality of the finish on the article being sprayed through appreciable varia-  
75 tions in gap distance, in a manner heretofore impossible.

Referring now more particularly to Figure 4, curves are shown illustrative  
80 of various conditions in electrostatic coating systems, both with and without the utilization of the present invention. The curve identified as 58 illustrates the gap break-down at various target  
85 spacings, where the target is an earthed article of flat sheet metal, and the atomizing bell has a 4 inch diameter atomizing edge with a radius of only about .005 inches, and connected to the  
90 negative terminal of a power supply unit having its positive terminal earthed. It will be seen that the gap breaks down at about 2 inches with 60 kilovolts, and at 3 inches with 90 kilovolts. The  
95 curve identified as 59a illustrates the voltage existing between the bell edge and the target at various spacings with atomizers and power supply units of the conventional type wherein the only  
100 appreciable resistance is a 10 megohm limiting resistor built into the power pack. With 90 kilovolts applied to the bell edge at a 12 inch spacing from the target, the curve remains substantially  
105 flat as the spacing is reduced, with a very slight drop in voltage in the last inch or two before the break-down distance is reached, this being at about  
110  $\frac{2}{3}$  inches and there still being almost 80 kilovolts at the bell edge.

The optimum atomizing voltage for a 4 inch bell as described above, being rotated at 900 rpm and supplied with 100 cc per minute of a conventional commercial synthetic enamel, is indi-  
115 cated by the dotted line curve identified as 59b. In order to obtain optimum atomization in an electrostatic system of the kind heretofore described the voltage existing across the gap between  
120 the atomizing edge and the target should follow this curve 59b as closely as possible. It will be apparent that the curve 59a of the conventional system is at the optimum atomizing voltage  
125 only at the 12 inch spacing and that material reductions in this spacing result in voltages greatly in excess of the optimum with attendant deterioration  
130 of the desired quality of atomization.

However, if the control resistance used in conjunction with a 100 kilovolt pack is 1500 megohms, the resultant curve (identified as 59c) will be seen to follow the optimum atomization curve 59b in a very satisfactory manner. That is, the curve 59c is never more than a very few per cent away from the optimum atomization voltage curve 59b at any point, and intersects the gap break-down line 58 when the spacing is less than 1 inch and when the voltage between the atomizing edge and the target has dropped below 30,000 volts. However, the curve is such that it not only closely follows the optimum atomization curve 59b but also provides in excess of 40,000 volts across the gap at all gap spacings of 2 inches or more, so that satisfactory atomization and deposition take place at spacing from 12 inches down to as little as 2 inches. On the other hand, if the resistance is of too high value, as for example, 50,000 megohms with a 100 kilovolt supply unit, the resultant curve (identified as 59d) will be seen to be so low at normal working spacings illustrated on the chart that satisfactory atomization and deposition are not obtained.

In order to achieve the desired automatic maintenance of the air gap voltage drop at or near the optimum atomization voltage in an electrostatic coating system of the character described and with present commercial power supply units of 100 kilovolts, the control impedance should be chosen to absorb only a small percentage (such as about 10%) of the applied voltage at the greatest gap space which is expected to be encountered in normal operation, but to absorb at least as much voltage as the air gap resistance at the lesser air gap spacings which may be encountered in operation. Again referring to the curve identified as 59c in Figure 4, it will be seen that the drop across the control resistance is about 15 kilovolts at the 12 inch spacing, but is approximately the same as the drop across the air gap when this spacing has been reduced to  $2\frac{1}{2}$  or 3 inches. It will be understood that this will be true with a relatively sharp edged device of the character described since the space current increases very materially as the gap spacing is reduced and thus enables the control resistance to absorb the desired amount of voltage drop there-across even through the air gap resistance decreases to an effective resistance of the same order as that of the control resistance. Moreover, it will be apparent from the chart that when the atomizing edge approaches as close as 1 inch to the target or article surface, in the

neighborhood of 70% of the voltage drop exists across the control resistance with only the relatively small remainder existing at the air gap.

An electrostatic spray painting system in which the series resistance is selected to give optimum atomization in this way forms the subject of our co-pending application No. 30969/80. (Serial No. 865,766)

While higher source voltages and higher control impedance values are preferable within certain limitations the cost of a power supply unit increases much faster than the increase in potential available from it, so that it is at present commercially desirable to limit the maximum voltage to be used to about 150 kilovolts. Under these conditions the resistance should be limited to the order of 15,000 megohms as a maximum in order to retain desirable atomization voltage variations and satisfactory deposition. It is to be understood, however, that where expense is not an important factor, power supply units can be built even today which provide voltages about double those mentioned above as being commercially desirable; and that improvements in power supply technology may well result in the ability to build even higher voltage units for general commercial use. However, our experiments have indicated that while the control impedance should be at least two megohms per kilovolt, and preferably of the order of 10 megohms per kilovolt or slightly more, it is undesirable to utilize more than about 100 megohms per kilovolt; and this relationship obtains throughout all voltage ranges which we believe likely to be used for electrostatic spray coating.

An important factor in the utilization of high voltages for electrostatic spray coating is the matter of safety, from the standpoint of ignition of the combustible mixture which exists when paint solvents volatilize in air. Certain solvents provide a more combustible mixture than others, one of the very commonly used paint solvents, xylene, providing a relatively ignitable mixture as it volatilizes into the air during spray painting.

With the present invention it is possible so to select the effective capacity which is presented at the exposed and accessible high voltage parts of the gun, and a suitably high value of resistance in the connection to those parts, that the danger of sparking, to an extent sufficient to cause ignition of a solvent vapour

mixture with air is avoided. With appropriate values for these quantities, we have found that even if the charging electrode is brought up undesirably close to the object, to the point where sparking occurs, as at a one-half inch spacing with control resistances of the value mentioned above, this sparking is so "weak", of such low average intensity or energy under condition where there is a low enough effective capacity beyond the control resistance, that even more ignitable mixtures than those normally encountered in a spray operation will not be ignited.

As mentioned above, some solvents are more easily ignited than others. It can be arranged that a gun has a margin of safety sufficient for all normally usable paints, but, if, as is frequently the case, a gun is used with selected paints only, it may be sufficient to ensure that the gun is adequately safe for that range of paints. In general, however, it is preferred to arrange that a gun is safe against fire hazard when used with all normal paints, so that the imposition of conditions upon its use can be avoided. The capability of a gun to cause ignition of a given solvent vapour is a test which can easily be carried out without danger in experimental conditions.

Similar considerations apply in the case of shock to an operator. Since electric shock is a subjective effect, the objectionable shock level is less easily ascertainable than, say the ignition level described above. Nevertheless, it is practicable to set a level at which objectionable shock occurs which will apply to all but a small minority of operators, and if desired the gun can be selected to avoid giving shock to virtually all operators, including the highly sensitive ones. It will be understood that the objectionable level is well below the danger level at which direct injury may occur.

Depending upon circumstances, for example upon the paint used, the fire hazard level may be less than or greater than the shock level, and depending upon the use for which the gun is intended. The design can be varied accordingly. The use of suitable low effective capacities with control resistance of the values described enables a low shock level to be achieved, so that no distress or injury to the operator will occur in the event the charged edge should be accidentally touched or approached too closely.

Even though a control resistance of 1000 or 2000 megohms is used, we have found that any high value of effective

capacity beyond the control resistance (i.e. between it and the charging electrode portion) will result in a spark, upon close approach to an article or operator, which will ignite a highly ignitable mixture and which will give such a distressing shock to the operator that few men will continue working with the system where they are exposed to occasional accidental shocks of this type. We have found by experiment that with control resistances of the values described the effective capacity ahead of such resistances must be extremely low. A 4 inch metal bell member has a capacitance several times the safe value, and well into the area where ignition and distressing shock would result even if a control resistance of many thousands of megohms were used; and thus the presence of a large object with its resultant geometric capacitance ahead of the control resistance presented another problem from the standpoint of safety.

We have enabled bells of these dimensions to be employed by the use of what might be termed very high distributed resistance in the discharge electrode, so that a spark originating at any one point does not provide a discharge of an intensity greater than that which can be tolerated. That is, even though the 4 inch bell member may have a true capacitance (as measured to a plate spaced one-half inch from its charging electrode edge portion) of about 10 micromicrofarads, the fact that the bell member has its main body portion of completely non-conducting material with the high resistance coating on the inner surface providing a very high point-to-point resistance, prevents the surface charge at one point on the bell from appreciably supplementing discharge at another point which comes too close to the article or the operator.

A conventional air spray gun or a conventional metal bell member of the type hereto-fore used in electrostatic spray coating would in both cases have such high capacitance and such good conduction of all the stored electricity to a point where a spark originates that neither would be safe, either as to ignition or distressing shock, even if control resistance of the values mentioned above were used between them and the high voltage source. By making any metal small enough, and by making a large body with a high geometric capacitance of such high distributed resistance that the quantity of electricity stored therein is not instantaneously available at a sparking point this

danger can be obviated. In considering effective capacity, as concerns safety, it will be understood that it is the energy at a sparking point which we have found to be important, and that physically large devices which have true geometric capacitance greater than those which could be tolerated can be rendered safe in conjunction with the control resistance by having a high distributed resistance therein or on the surface of a substantially non-conducting body member. It is also to be understood that there is some relationship between the value of the control resistance and the amount of capacity which can be tolerated; but we have found that with control resistance of the character described, as, for example, in the order of 1000 megohms with 100 kilovolts applied from the negative terminal of a supply having its positive terminal earthed, the energy of a disruptive discharge, to an earthed polished metal sphere of about one centimetre radius from an electrode ahead of the control resistance, should preferably not exceed that from a polished metal sphere having a radius of about one centimetre replacing the electrode in the same system, and in any event should not exceed that from a sphere having a radius of about three centimetres.

We have found that a satisfactory and reproducible measurement of the amount of effective capacity which can be tolerated can be obtained by using polished metal spheres of different diameters as the electrode beyond the resistor. Such a sphere has a capacitance to an infinite earth around it which varies as its radius and which is about 1 micromicrofarad per centimetre of radius. Moreover, the capacitance at a spacing of even a very few inches from an earthed object (such as a metal plate) is very close to the theoretical capacitance to an infinite earth. For example, a polished metal sphere having a radius of 1 centimetre has a capacitance to infinite earth of 1.1 micromicrofarad; and even when a flat earthed metal plate is brought within  $\frac{1}{2}$  inch of it, its capacitance as measured to the plate is only about 1.4 micromicrofarad. Accordingly, a polished steel sphere mounted on the end of the resistance element being used can be brought closer and closer to an earthed metal member (such as the sphere of one centimetre radius mentioned above) or to the end of the finger of an operator, until a disruptive discharge takes place, and the energy level of such discharge is very reproducible with a given bell, resistor and applied voltage. For example, a polished steel sphere of 1 centimetre

radius mounted on the end of 1000 megohms resistor provides an unobjectionable discharge at any applied voltage below and up to 100 kv. The discharge from such a combination does not provide a disagreeable shock to the person and has too low an energy level to ignite mixtures of the most readily ignitable nature, such as a saturated mixture of hexane and air, at 3°F and at atmospheric pressure.

Higher resistor values (as for example 4,000 megohms), lower applied voltage (as 50 kv), and somewhat less ignitable solvents commonly used in painting, as toluene or xylene, permit the effective capacity to be about that of a sphere having a radius of 3 centimetres without objectionable shock and without danger of ignition of the most combustible vapour-air mixture possible in the spraying zone, such as a saturated mixture of toluene and air at 82°F or xylene and air at 115°F. In considering whether a gun is safe from fire hazard, in the absence of an indication of the specific paint with which the gun is intended to be used, either the toluene-air or xylene-air mixture can be used in estimating safety. A gun can be considered as 'safe' if it is safe when operated in such a mixture. It will be understood that the use of a polished metal sphere is for comparative or test purposes only, and that such would not be used as a charging electrode in the normal electrostatic spray painting system. The energy level of the discharge from a polished metal sphere of 1 centimetre radius energized through a 1,000 megohm resistor, however, is about the same as that of a 10-inch wire having a diameter of .050 inch similarly energized. Such a wire may be used very satisfactorily as a charging electrode when atomization is separately effected, as will be hereinafter more fully described, or may be considered analagous to the atomizing edge of a 4-inch diameter non-metallic bell with highly distributed resistance, as heretofore described.

While the power supply unit provides a high voltage supply which is commercially regarded as direct current, it will be understood that this is not pure direct current in the absolute sense. In commercial practice the power unit has its input connected to a conventional 50-cycle alternating current supply, and the high voltage output is rectified and partially filtered to provide a uni-directional field-creating voltage; but there is, of course, still an appreciable amount of

"ripple". Accordingly, while we prefer to use a pure resistance as the control means, any impedance which achieves the desired control action may be utilized. Also, while the control action in the embodiment just described is a result of the total effective resistance provided by two parallel resistances (one being the resistor and the other being the resistance of the paint column), it is to be understood that the desired control impedance can be achieved in a number of ways. For example, it may be achieved by the use of carbon, metallic oxide, or other commercial resistors; by equipment components made of or coated with materials having the desired resistance characteristics; by the resistance of the paint column or film; by the inter-element impedance of a high voltage vacuum tube (which would be located outside the gun); or by combinations of the above or other suitable impedances.

It is to be observed that with a conventional power supply unit such as the transformer rectifier arrangement mentioned above, the voltage that is obtained from the unit can be regarded, for practical purposes, as being unresponsive to the output current. This point will be apparent from Figure 4, curve 59a, where the voltage (even with the included 10 megohms in the circuit) varies by a relatively small percentage with target spacing and hence target current. The present invention is not limited to the use of a power supply unit having this characteristic and is to be considered as extending to the use of power units other than those where the available potential of the source is relatively unresponsive to current changes. Whatever type of power unit is adopted, it will of course be arranged that the electrical circuit extending to the charging electrode and including the voltage source is responsive to changes in the length of the air gap so as to reduce the voltage of the charging electrode as the air gap between the gun and the article or earthed object decreases, to ensure that objectionable discharge can be avoided, as described above.

Referring now more particularly to the embodiment of the invention shown in Figure 5, a modified form of a hand-held atomizing device is identified in general as 40. In this device three separate connections are made to the rear of the device, although for convenience the three separate conduits 41, 42 and 43 are brought together into a single flexible conduit assembly preferably covered with an earthed flexible

metallic outer sheath 44. The bell member 45 is mounted upon a rotatable shaft 46 connected to a flexible drive shaft in the conduit 42. In this embodiment of the invention, the bell member 45 is again of non-conducting material, such as nylon, with a surface layer 47 of predetermined resistance; but in this case the resistance layer 47 is on the exterior of the bell member while paint flows on the inner surface, contact between the paint and resistive layer occurring only at the atomizing edge 45a. High voltage is brought in through the electrical conduit or lead 41, passes through two fixed resistors 48 and 49 which may be, by example, of 500 megohms each, with the two providing a total extent of about 12 inches. The forward end of resistor 49 is electrically connected to a very small metal leaf spring 50 which makes rubbing contact with a portion of the resistive coating 47 to transfer current thereto.

This embodiment of the invention includes a liquid control valve in the atomizing device itself, the actuating member for the valve being the trigger element 51 pivoted at 52 on a handle 53. When the parts are in the position illustrated a valve member 54 closes off the liquid supply conduit 43, being urged to closed position by a spring 55. When the lower end of the trigger element 51 is pulled toward the handle 53, however, its engagement with the valve actuating member 56 lifts the valve 54 off its seat, and paint can then flow through the passageway 57 to the hollow shaft 46, and thus through the axial opening in the bell member to spread out in a film on the inner surface thereof and move to the atomizing edge as a result of the rotation of the bell.

In this embodiment of the invention the flexible shaft and the paint supply conduit can be earthed, since they are isolated from the high voltage electrical supply, and thus the rotating motor and the paint supply means can be merely set on the floor or be otherwise suitably supported, but without the need of any high voltage insulation. Moreover, since there is a control valve in the atomizing device, no pump need be used for the paint, but instead the paint can be supplied if desired from a simple pressure container (generally termed a "pressure pot") having air under pressure (for example, at 30 pounds per square inch) over the paint. Moreover, the handle and trigger can be of metal and earthed by being



electrically connected to the earthed metal sheath 44. This results in a situation where any failure of insulation could not result in shock to the operator.

5 While this embodiment has series or control resistance analagous to that of the first described embodiment, it is to be noted that in this form in Figure 5 the resistance of the paint column  
10 extending from the valve chamber to the atomizing edge is in parallel with the air gap resistance between the edge of the bell and the article being coated, rather than being in parallel with the  
15 resistors 48 and 49. This results from the fact that the paint column is earthed at the valve portion of the device, so that it is in effect connected to the same terminal of the power supply unit  
20 as the article, the bell edge potential and the average potential gradient of the field, during variations in gap spacing between the bell and the article being thus controlled in part by the series  
25 resistors 48 and 49, and in part by the parallel impedance provided by the paint column. Where the paint has a resistance characteristic such that passageway diameters and lengths will fall within  
30 reasonable and practical values to achieve desired resistances, better control of the charging electrode portion voltage can be obtained in some circumstances. It is also to be understood that  
35 if the paint is kept completely insulated from earth and at high potential in this form, or is of such high resistance as to be substantially completely non-conductive, similar control may be obtained by  
40 utilization of another impedance between the charging electrode (here the edge portion of the bell) and earth in conjunction with the series resistance provided by the resistors 48 and 49.

45 In connection with the electrostatic atomization effected in both of the embodiments heretofore described, we have found that the high series resistance can be selected to maintain the atomizing  
50 edge at or near optimum atomizing voltage as the gap spacing is varied. It has heretofore been thought that at least one fifth of a milliampere of current was necessary for suitable electrostatic  
55 atomization, but we have found that we can not only retain good atomization and charging of the spray particles, but even improve these, with currents of the order of one-twentieth of this, or even less,  
60 as about 10 microamperes. This discovery has enabled us to use resistances of several thousand megohms in conjunction with the power supply voltage of 100 K.V.

65 Important control and safety aspects of this invention can also be embodied

in systems wherein the depositing field extends from the article to an opposite electrode which is not a part of the atomizing device, and a representative system of this type is shown in  
70 Figures 6 and 7. Four small electrode wires 71a-d are arranged horizontally in a single plane with their ends one foot apart at what may be considered the  
75 corners of a square, as may best be seen in Figure 7. These field electrodes are supplied with current through control resistance means 72a-d, these resistances  
80 having values of the character heretofore described and being of sufficient length that there is no danger of arcing around  
85 from the electrode wire 71 to the lead 73 from the high voltage supply pack 74. A conventional air spray gun 75 is illustrated as mounted on a support  
90 pedestal 76, the gun and pedestal being at ground potential and uninsulated, although it is to be understood that the spray gun can be hand-held and freely  
95 movable. Paint from a supply tank 77 is delivered through the hose 78 when compressed air is supplied to the gun through the hose 79. The axis of the  
100 spray gun intersects the centre of the square formed by the tips of the electrode wire 71, but to one side of the plane of the electrode wires, as for example, 8 inches therefrom. On the  
105 opposite side of the plane of the electrodes is an article 80 here illustrated as a bread box, carried by a conveyor spindle 81 with rotating means including the wheel element 82  
110 bearing against a rotating rail 83. It will be understood that articles are moved in succession through the coating zone by the conveyor and their rotation during the coating causes the corners to be much closer to the electrode wires than the centre of the wall  
115 panels. It is also to be understood that a slightly bent or loose spindle or an article improperly positioned on the spindle would, of course, result in even greater variations in the distance  
120 between the spray charging electrodes 71 and the article being coated. In the past, protection against such variations has been obtained by utilizing a much greater electrode-to-article  
125 spacing than would be desirable from the stand-point of deposition efficiency. Where the closest approach of an article portion anticipated to occur in normal operation is double the sparking distance for the voltage used, it is obvious that the average potential  
130 gradient will be at about the minimum of the desirable working range when such closest portion is presented;

and that when the centre portions of the walls of the bread-box illustrated are being presented toward the spray gun, or if the article wobbles somewhat further away as a result of a bent spindle, the field gradients will be substantially below the desired value. This results in the air blast blowing away more spray particles than would be the case if the average field gradient were at all times at a desirably high level. While electrostatic effects have advantage with average potential gradients of about 5,000 volts per inch at the six to twelve inch spacings being discussed, average gradients of well over 10,000 volts per inch are desirable for maximum deposition efficiencies in a system of this character.

In the system illustrated, the side walls of the bread-box, when presented directly toward the spray gun by a straight spindle having the article properly positioned thereon, may be located only 6 inches from the electrode wires although a 100 KV power pack is being used. With a resistor 72 absorbing about 10% of the voltage, about 90,000 volts would exist on the electrode wires 71 and the average potential gradient of the field to the articles under the conditions just described would thus be about 15,000 volts per inch. Even if a bent spindle or any improper positioning or swaying of the article results in distance increasing a couple of inches, the average potential gradient is still in excess of 10,000 volts per inch. Yet as the article rotates and presents a corner directly toward the spray gun, or if some other factor causes it to come closer, reduction in the gap distance between the electrode wires and the closest article portion (as for example to 3 inches) still permits an operative and highly efficient field to exist, the resistor absorbing sufficient voltage drop in the system to prevent any disruptive discharge down to a very close spacing, such as one-half inch or one inch, and prevent it from being objectionable even then.

We have found it desirable to have the electrodes of appreciable length, extending preferably at least several inches from the resistors, a very satisfactory embodiment of this invention having been constructed with each electrode wire being 6 inches long. The highly ionizing effect of a small wire (such as a wire ten thousandths of an inch in diameter) repels the paint and not only charges the spray but also creates conditions which keep the spray from painting back onto the remotely located sheaths or covers of the resistance elements, which is

unsatisfactory. Moreover, the "sharp" configuration of such a fine wire, with attendant higher space currents across the air gap than would occur from a polished sphere or other "blunt" electrode, has a desirable action in connection with the control effect of the resistor, and in minimizing the effective capacity of a given electrode size. The conditions as to capacitance must still be observed, however, and the size of the metal electrode should be kept small enough that the discharge therefrom should preferably not exceed that from a metal sphere of one centimetre radius, or in any event should not exceed that from a metal sphere of three centimetres radius.

In addition to using electrode wires having a length of at least several inches, but not exceeding a suitable capacitance, we find that where a plurality of electrode wires are used and supplied with current through independent control impedances, the electrodes should be spaced at least several inches apart. If the electrodes are too close together an operator or article can touch several of them at once and this would result in an objectionable discharge since the capacitance and impedances would all be effectively in parallel under such conditions. With the use of a system of the character embodying the above discussed factors, however, safety considerations are retained while achieving high average field intensities despite appreciable variations in gap distance, with resultant improved deposition efficiency. In a system constructed in accordance with the disclosure of Figures 6 and 7, for example, used in the spray coating of metal broom handles 1 inch in diameter and spaced on 3 inch centres, deposition efficiency with such a system was about 10% better than with the same electrode and spray gun arrangement without the control impedance and with the path of article movement then being 12 inches from the electrode rather than 6 inches in view of the necessity of being double the possible arcing distance.

In a system utilizing charging electrodes separate from the atomizing device, as illustrated in Figures 8 and 7, average gradients which are in excess of 10,000 volts per inch, and preferably 15,000 volts per inch or more, are desirable for maximum deposition efficiency at spacings of six to twelve inches, for example. In the absence of a control resistance the minimum gap space between the



electrode and article would normally be required to be about 12 inches with a 100 KV supply unit, with the average potential gradient then being a little less than 10,000 volts per inch and dropping rapidly as the gap is increased by rotation of the article, or swaying of the article away from the electrode. We have found that very much improved deposition efficiencies can be achieved, particularly upon articles presenting a substantial amount of "open space" relative to the metal surface being coated, by not only utilizing control resistance means but also by materially raising the power pack voltage beyond that which would otherwise normally be used, and have obtained very desirable results by use of a 160 KV power supply unit with appropriate control resistances. For example, if a 5,000 megohms control resistance is used with a 160 KV power supply unit, the spacing arrangement can be such that if the minimum spacing encountered is 4 inches, the average potential gradient at that spacing would be about 18,000 volts; and yet at a 12 inch spacing the gradient would still be about 10,000 volts per inch. This is less than a 2 to 1 change of average gradient for a 3 to 1 change in gap spacing; and enables the average gradient to normally be at or about 15,000 volts per inch, with the gradient at the large 12 inch spacing still being about 10,000 volts per inch. The geometry and surface area of atomizing devices of the character heretofore generally used commercially may provide an objectionable disruptive discharge even when suitable control impedances are used in series therewith. We have found that large area atomizing devices, such as atomizing bells or hand guns effecting mechanical atomization can have their effective capacities reduced to a suitable value by being made substantially entirely of non-conductive material with a high distributed resistance. Where it is desirable to use a metal electrode, making it not only of small capacitance and preferably relatively "sharp", as by using a wire electrode of small diameter, achieves the desired low effective capacity.

This application is divided from application 9173/57, (Serial no. 865,763) from which are divided also applications 27822/60, 30989/60, 31139/60 and 33146/60. (Serial nos. 865,764, 865,766, 865,767 and 865,768.)

#### WHAT WE CLAIM IS:-

1. Apparatus for electrostatically spray painting an article, said article being substantially at earth potential,

comprising a gun, capable of use in circumstances where the air gap between the gun and the article or earth is liable to fortuitous variation, said gun including a charging electrode, and means for establishing an electrical circuit including the earthed article, a unidirectional high potential source and said charging electrode, said gun being adapted in use to atomise paint and introduce said atomised paint into the field between the charging electrode and the article, wherein (a) the electrical circuit including said source is so responsive to changes in the length of said air gap as to reduce the voltage of said charging electrode sufficiently as the air gap between the gun and the article or other earthed object decreases, and (b) the charging electrode and any other parts of the gun which are at high potential in use and are manually or otherwise externally accessible have an effective capacity that is sufficiently low, to ensure that any discharge of electricity therefrom which will create fire hazard is avoided.

2. Apparatus for electrostatically spray painting an earthed article, said article being substantially at earth potential, comprising a gun capable of use in the hand or in circumstances where a human operator has access to the gun, said gun including a charging electrode, and means for establishing an electrical circuit including the earthed article, a unidirectional high potential source and said charging electrode, said gun being adapted to atomise paint and introduce said atomised paint into the field between the charging electrode and the article, the charging electrode and any other parts of the gun that are at high potential and are manually accessible in use having an effective capacity that is low and the electrical circuit including said source being so responsive to changes in the length of the air gap between the charging electrode and the article or operator as to reduce the potential of such part or parts sufficiently in relation to their effective capacity as the air gap decreases, to ensure that objectionable shock is substantially eliminated.

3. Apparatus for electrostatically spray painting an article, said article being substantially at earth potential comprising a gun capable of use in circumstances where the air gap between the gun and the article or earth is liable to fortuitous variation, said

- gun including a charging electrode, and means establishing an electrical circuit including the earthed article, a unidirectional high potential source and said charging electrode, said gun being adapted to atomise said paint and introduce said atomised paint into the field produced, in which, as the air gap decreases in length, the voltage on the charging electrode falls not less rapidly than at a rate equivalent to that due to the inclusion in said circuit of a resistance of a value of two megohms per kilovolt of the voltage available at the source, and the electrode and any other manually or externally accessible parts have a low effective capacity, thereby ensuring that discharge is avoided which is objectionable as to fire hazard, or to shock to an operator, or both.
4. Apparatus for electrostatically spray painting an article, said article being substantially at earth potential, the apparatus being arranged to be supplied with paint and to introduce the atomised paint into an electrostatic field for deposition on to the article, and including an electrode between which and the article the electrostatic field is established, and an electrical circuit including a source of unidirectional voltage connecting the electrode to earth, the voltage being sufficient for efficient deposition, the electrode having an effective capacity not exceeding that of a polished metal sphere of 3 cms. radius and the effective impedance of the said circuit being at least 10 megohms per kilovolt of the source.
5. Apparatus for electrostatically spray painting an article, said article being substantially at earth potential, the apparatus being arranged to be supplied with paint and to introduce the atomised paint into an electrostatic field for deposition on to the article, and including an electrode between which and the article the electrostatic field is established, and an electrical circuit including a source of unidirectional voltage connecting the electrode to earth, the voltage being sufficient for efficient deposition the electrode having an effective capacity not exceeding that of a polished metal sphere of 1 cm. radius and the effective impedance of the said circuit being at least 3 megohms per kilovolt of the source.
6. Apparatus for electrostatically spray painting an article, said article being substantially at earth potential, the apparatus being arranged to be supplied with paint and to introduce the atomised paint into an electrostatic field for deposition on to the article, and including an electrode between which and the article the electrostatic field is established, and an electrical circuit including a source of unidirectional voltage connecting the electrode to earth, the voltage being sufficient for efficient deposition, the effective impedance of said circuit being greater than 100 megohms, the electrode having an effective capacity low enough to ensure that discharge is avoided that is objectionable.
7. Apparatus for electrostatically spray painting an article, said article being substantially at earth potential, comprising a gun, capable of use in circumstances where the air gap between the gun and the article or earth is liable to fortuitous variation, said gun including a charging electrode, and means for establishing an electrical circuit between a unidirectional high potential source and said charging electrode, said electrical circuit effectively including an impedance of which a substantial part is located near said charging electrode, said gun being adapted in use to atomize paint and introduce said atomized paint into the field between the charging electrode and the article, wherein (a) said electrical circuit is so responsive to changes in the length of the said air gap as to reduce the voltage of said charging electrode sufficiently as the air gap between the gun and the article or other earthed object decreases, and (b) the charging electrode and any other parts of the gun which are at high potential in use and are manually or otherwise externally accessible have an effective capacity that is sufficiently low, to ensure that any discharge of electricity therefrom which will create fire hazard substantially avoided.
8. Apparatus for electrostatically spray painting an earthed article, said article being substantially at earth potential, comprising a gun capable of use in the hand or in circumstances where a human operator has access to the gun, said gun including a charging electrode, and means establishing an electrical circuit between a unidirectional high potential source and said charging electrode, said electrical circuit including an impedance of which a substantial part is located near said charging electrode, said gun being adapted to atomize paint and introduce the atomized paint into the field between the charging electrode and the article, the charging electrode and any other parts

of the gun that are at high potential and are manually accessible in use having an effective capacity that is low and the electrical circuit being so responsive to changes in the length of the air gap between the charging electrode and the article or operator as to reduce the potential of such part or parts sufficiently in relation to their effective capacity as the air gap decreases, to ensure that objectionable shock is substantially eliminated.

9. Apparatus for electrostatically spray painting an article, said article being substantially at earth potential, comprising a gun capable of use in circumstances where the air gap between the gun and the article or earth is liable to fortuitous variation, said gun including a charging electrode, and means for establishing an electrical circuit between a unidirectional high potential source and said charging electrode, said electrical circuit including an impedance a substantial part of which is located near said charging electrode, said gun, being adapted to atomize paint and introduce said atomized paint into the field produced, in which, as the air gap decreases in length, the voltage between the charging electrode and the article falls not less rapidly than at a rate equivalent to that due to the inclusion in the circuit of an effective resistance of two megohms per kilovolt of the voltage available at the source, the electrode and any other manually or externally accessible parts having a low effective capacity, whereby discharge is substantially avoided which is objectionable as to fire hazard, or to shock to an operator, or both.

10. Apparatus for electrostatically spray painting an article, said article being substantially at earth potential, the apparatus being arranged to be supplied with paint and to introduce the atomized paint into an electrostatic field for deposition on to the article, and including an electrode between which and the article the electrostatic field is established, and an electrical circuit extending between a source of unidirectional voltage and the electrode, said electrical circuit including an impedance of substantial value located near said charging electrode, the voltage being sufficient for efficient deposition, the electrode having an effective capacitance not exceeding that of a polished metal sphere of 3 cms. radius and the effective impedance of the said circuit being at least 10 megohms per kilovolt of the source.

11. Apparatus for electrostatically

spray painting an article, said article being substantially at earth potential, the apparatus being arranged to be supplied with paint and to introduce the atomized paint into an electrostatic field for deposition on to the article, and including an electrode between which and the article the electrostatic field is established, and an electrical circuit extruding between a source of unidirectional voltage and the electrode, said electrical circuit including an impedance, a substantial part of which is located near said charging electrode, the voltage being sufficient for efficient deposition, the electrode having an effective capacitance not exceeding that of a polished metal sphere of 1 cm. radius and the effective impedance of the said circuit being at least 3 megohms per kilovolt of the source.

12. An apparatus in accordance with any of the preceding claims, wherein the atomization of the paint is effected electrostatically.

13. An apparatus in accordance with Claim 12 wherein the electrode serves also to effect atomization.

14. An apparatus in accordance with Claim 13, wherein the atomizing electrode is rotatable, and presents a generally circular edge on which a film of paint is established in use.

15. An apparatus in accordance with Claim 14, and comprising means for presenting a current path from the said high voltage source to said edge.

16. An apparatus in accordance with any of the preceding claims, wherein said electrode has an accessible part thereof made of material having a high resistance whereby the effective capacity of the electrode is reduced.

17. An apparatus in accordance with Claim 16, wherein the electrode is made partly of insulating material, and partly of material of high resistance.

18. An apparatus in accordance with Claim 17, wherein a high resistance path is provided by a coating on the surface of the member of insulating material.

19. An apparatus in accordance with Claim 5, 11, 16, 17 or 18 wherein the resistance presented by the impedance element, or the element and the said electrode together, has a value of at least 3 megohms per kilovolt of the voltage of the source, but not exceeding 100 megohms per kilovolt, the effective capacity of the high voltage accessible parts not exceeding that of a polished metal sphere of 1 cm. radius.

20. An apparatus in accordance with

- Claims 4, 10, 16, 17, or 18 wherein the resistance presented by the impedance element, or the resistor and the charging electrode together, has a value of at least 10 megohms per kilovolt of the voltage of the source, but not exceeding 100 megohms per kilovolt, the effective capacity of the high voltage accessible parts not exceeding that of a polished metal sphere of 3 cms. radius.
21. An apparatus in accordance with any of the preceding claims, wherein said high voltage source established at an appropriate working spacing between the electrode and the article, a potential difference of at least 40,000 volts at the air gap between the said electrode and the article.
22. An apparatus in accordance with any of the preceding claims, wherein said voltage source establishes at an appropriate working spacing between the electrode and the article a potential gradient across the air gap of at least 5,000 volts per inch of air gap between the said electrode and the article.
23. An apparatus in accordance with any of Claims 4 to 22 wherein paint in said gun provides a current path which is electrically in parallel with said impedance element.
24. An apparatus for electrostatically painting an earthed article, comprising a charging electrode and capable of use in circumstances where the air gap between the charging electrode and the article or earth is liable to fortuitous variation, means connecting the article in an electrical circuit extending from a unidirectional high potential source to said charging electrode, means for atomizing paint and introducing said atomized paint into said field, wherein said electrical circuit is so responsive to changes in the length of said air gap as to reduce the voltage of said charging electrode sufficiently as the air gap between the charging electrode and the article or other earthed object decreases and the charging electrode and any other parts which are at high potential in use and are manually or otherwise externally accessible have an effective capacity that is sufficiently low to ensure that any discharge of electricity therefrom is unobjectionable, either as to shock or fire hazard or both.
25. An apparatus in accordance with Claim 24, wherein said electrical circuit includes an impedance of substantial value located near said electrode, and as the air gap decreases in length, the voltage on the charging electrode falls not less rapidly than at a rate equivalent to that due to the inclusion in the circuit of a resistance of a value of at least two megohms per kilovolt of the voltage available at the source.
26. An apparatus in accordance with Claim 25, wherein said electrode has an effective capacitance not exceeding that of a polished metal sphere of 3 cms radius and the effective impedance of the circuit is at least 10 megohms per kilovolt of the source.
27. An apparatus in accordance with Claim 25 wherein said electrode has an effective capacity not exceeding that of a polished metal sphere of 1 cm radius, and the effective impedance of the circuit is at least 3 megohms per kilovolt of the source.
28. An apparatus in accordance with Claim 25 or 27, wherein the effective impedance of said circuit does not exceed 100 megohms per kilovolt of the source.
29. An apparatus in accordance with any 90 of Claims 24 to 27 and comprising a plurality of spaced charging electrodes, the connection between the voltage supply and each said electrode being separately completed through an impedance element located immediately adjacent to the effective charging portion.
30. An apparatus in accordance with Claim 29, wherein each said electrode has an effective capacity not greater than 100 that of a polished metal sphere of 1 cm radius.
31. An improved apparatus for electrostatic paint spraying substantially as herein described with reference to the accompanying drawings.
32. A method for electrostatically spray painting an earthed article, which comprises establishing an electrostatic field between a charging electrode and the article by means of a voltage source, the air gap between the charging electrode and the article or earth being susceptible to fortuitous variation into a range where objectionable discharge is liable to occur, which comprises supplying paint to an atomizer and introducing atomized paint into the field and including controlling automatically the potential across said air gap in accordance with variations of the length of the air gap in such a manner that with a decreasing length of air gap the potential falls at a rate not less rapidly than that due to the inclusion in the circuit to said charging electrode of a resistance of two megohms per kilovolt of the source, whilst maintaining the effective capacity of the charging

electrode not greater than that which would be provided by a metal sphere of a radius of 3 cms.

33. A method in accordance with Claim 32 which comprises establishing at least 40,000 volts in operation between the charging electrode and the article, the connection to said charging electrode including a resistance of at least 10 megohms per kilovolt of the voltage of said supply.

34. A method in accordance with Claim 32, which comprises maintaining said effective capacity not greater than that of a sphere of 1 cm radius, the connection to said charging electrode including effectively a resistor of at least 3 megohms per kilovolt of the voltage of the supply.

35. An improved method of electrostatic spray painting substantially as herein described with reference to accompanying drawings.

36. Articles painted by an apparatus or method in accordance with any of the preceding claims.

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Fig. 6

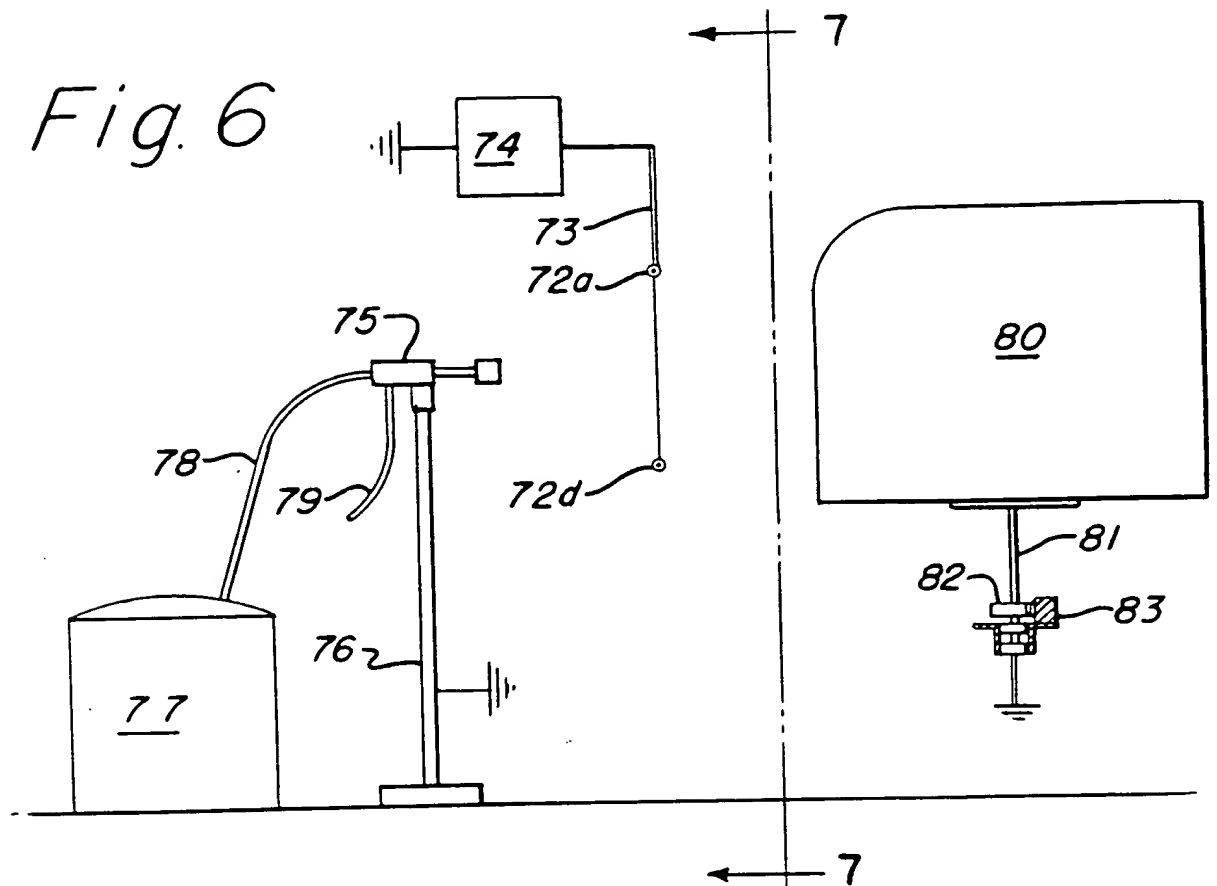
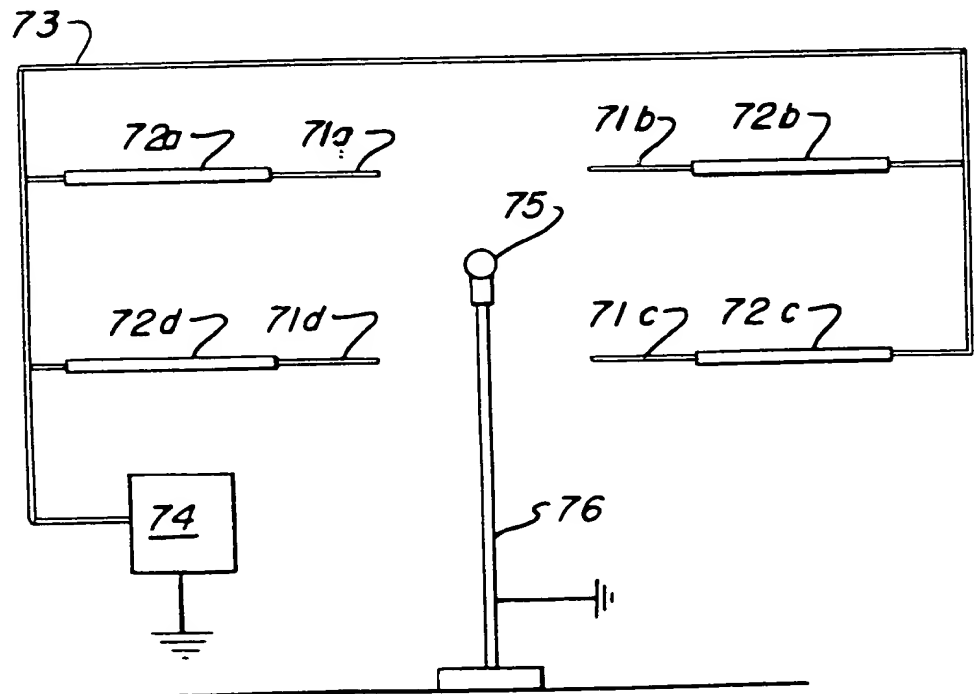


Fig. 7



865,765 COMPLETE SPECIFICATION

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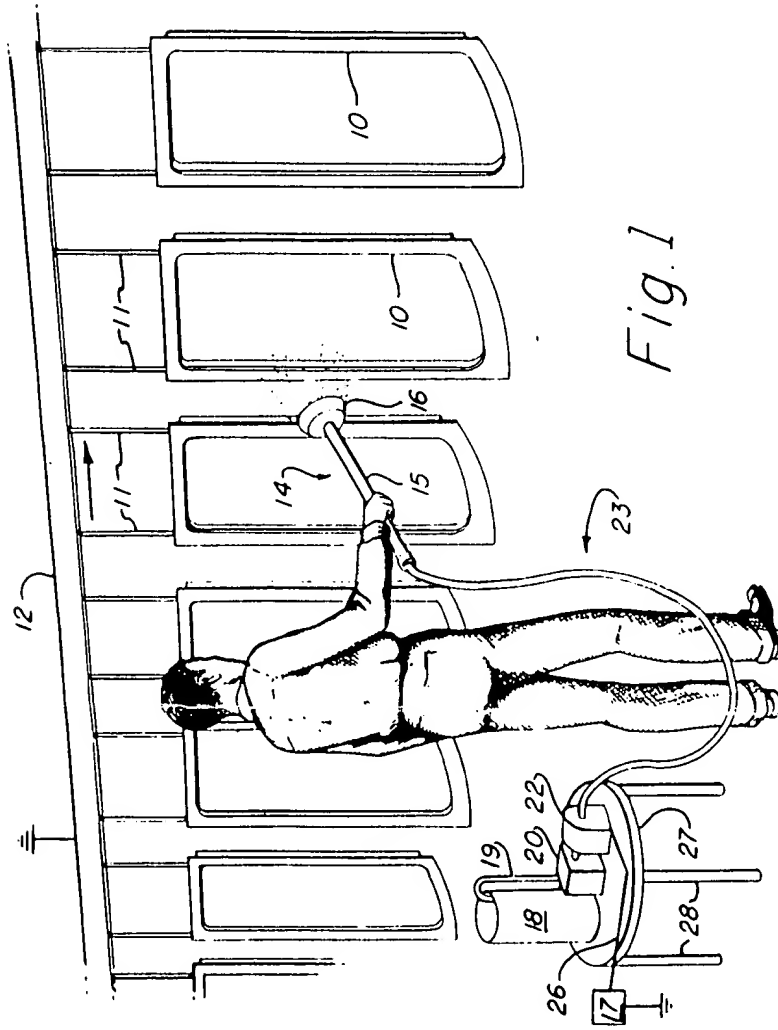
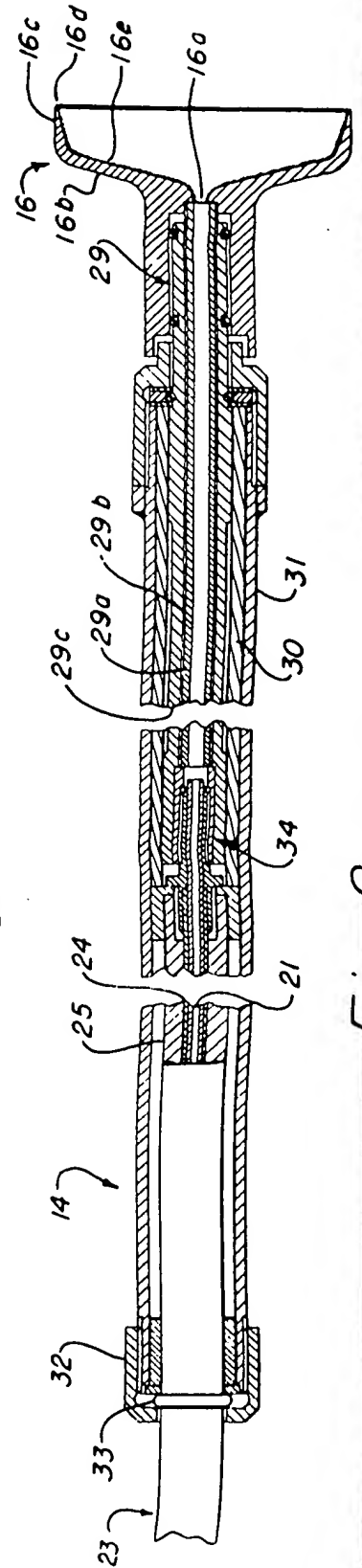


Fig. 1





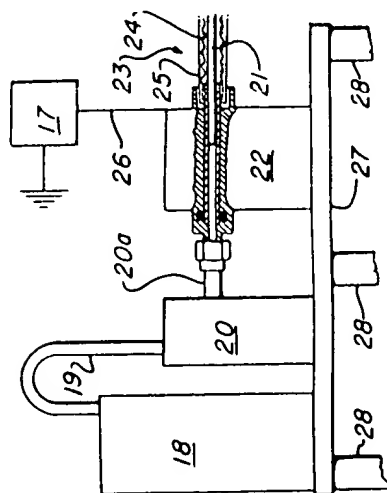
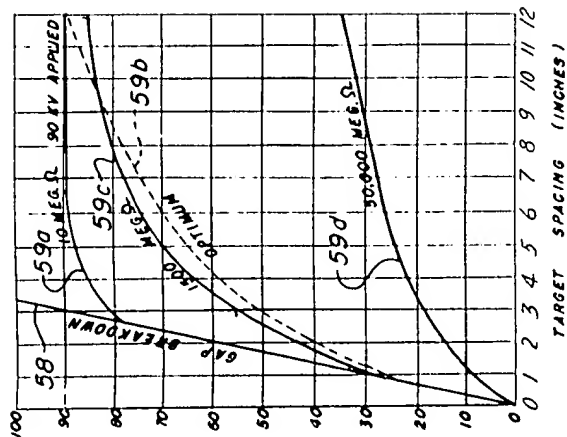


Fig. 3

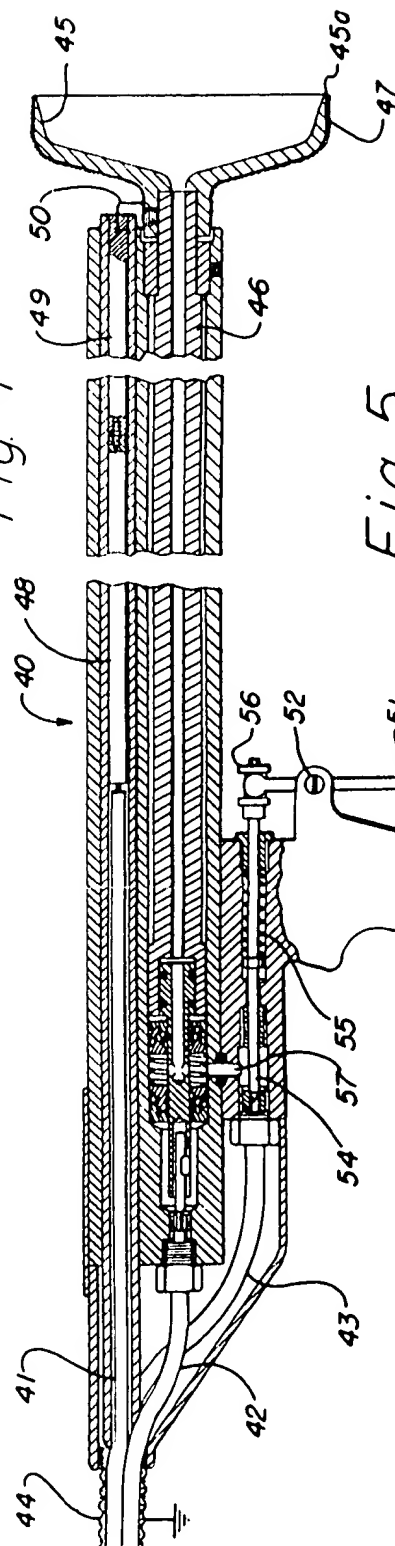


Fig. 4

Fig. 5

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